there is a preponderance of explosions about the time that the central areas of anticyclones lie over our own coal-fields. Until Prof. Louis can prove that this statement, made by an independent investigator, is wrong, those who study the question with an open mind will not readily acquiesce in his theory, which requires the presence of a cyclonic area to bring about a disaster. True, Mr. Dobson's report to the British Association, and the papers to the Royal and the Meteorological Societies by Messrs. Scott and Galloway, were based on the theory that a low and falling barometer was necessary; but a glance at their diagrams is sufficient to show that accidents under a high barometer were attributed to a falling barometer at some other time, Mr. Dobson going so far away as a fortnight from an explosion to get a barometric fall to satisfy the theory. But when Messrs. Scott and Galloway had completed their inquiry from the purely theoretical side, the diagrams were ready, and the percentages of accidents under different conditions had been worked out, recourse was had to the very simple device of looking up the facts. Mr. Galloway was permitted to examine a large number of report books kept at mines in Scotland in 1873. To the amazement of the authors, they "found that sometimes a sudden fall of atmospheric pressure has taken place without causing gas to appear, and sometimes gas has suddenly appeared in considerable quantity when the pressure was high and steady." Before the Royal Commission of 1879–86, an experienced mining engineer, Mr. F. Wardell, stated that from his own observation explosions occurred generally on a rising barometer; and Mr. (now Sir) Henry Hall, the well-known Inspector of Mines, declared:—"More of the large accidents that have happened in my hands have happened when the glass was high, than otherwise." Evidence in

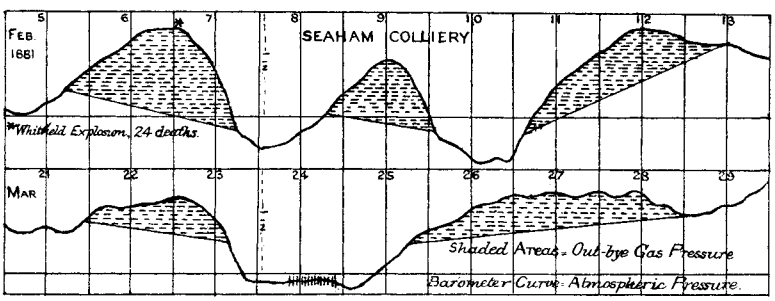

FIG. 1.

support of these statements could be multiplied to any extent, and those who are interested in the question, instead of treating the evidence as merely amusing, should seriously endeavour to arrive at a reasonable explanation of the appearance of dangerous volumes of gas in mines when the barometer is rising or stands high.

There was a time when no one guessed that the earth's crust was always on the move, wobbling like a jelly; but Darwin started a new idea, declaring that the time would come when scientific men would no more regard the earth as immovable for any length of time than they would believe in an everlasting calm in the atmosphere. Since that declaration we have advanced a long way on the road towards proving the earth's crust, no longer supposed to be a rigid mass, liable to rise and fall under the vast changes of atmospheric weight indicated by barometric variations. To miners it has been a matter of common observation that earth movements are of frequent occurrence, and the evidence before the Royal Commission of 1879 showed that strong rock-roofs are either actually forced down or become much curved, eventually recovering their normal position when the gas-pressure is diverted in some other direction. The great disaster at Abercarne on September 11, 1878, when 268 lives were lost, had been preceded by outbreaks of gas daily from September 5 to 10, consequent upon a squeeze or settling down. Since the beginning of the month high barometric pressure had ruled—30·25 inches at Abercarne on the day of the disaster.

The Seaham records demonstrate clearly that there is an intimate relationship between the movements of the barometer and the pressure of the gas existing in sealed-up places in the earth—not the gas in the open goaf, which is acted upon directly by the air-pressure. The gauge inserted in the sealed-up reservoir of the Hutton seam showed that on every occasion when the barometer rose, even as on March 24, 1881, when it was at a very low level, the imprisoned gas showed an out-bye pressure, indicating that it was being compressed (Fig. 1). When the barometer was at its lowest, the compression ceased, and the gauge indicated an in-bye pressure. Those who discussed the observations were mystified; they could not get over the facts disclosed, and the only escape from the dilemma was by deciding that it was all the fault of the barometer—that it was not sensitive enough to fall twenty, thirty, or forty-eight *hours* sooner than it does! No physicist who has studied the action of the instrument would admit that, even supposing there is any lag, it would amount to as many *seconds*. It is a more reasonable suggestion that the increase of barometric pressure weighs down the earth's crust, and this, acting upon the imprisoned gas, increases its pressure. It is under these high-pressure conditions that Colliery Warnings have been issued through three decades, and it is under these same conditions that the worst explosions take place, for they are associated with great outbursts of gas flooding the workings suddenly, and not with the almost inappreciable, regulated flow of gas from the open goaf under a low and falling barometer.

THE AUTHOR OF THE WARNINGS.

I AM delighted to find that my article on this subject has drawn a reply from the Author of the Warnings, though I must admit to disappointment at the character of his letter. In my article I stated certain facts as to the occurrence of firedamp in collieries, and showed how this gas must behave under varying barometric pressure in accordance with well-known physical laws; to my mind, there is only one proper way of controverting conclusions thus arrived at, and that is to show where I am mistaken in my statement of facts, in my enumeration of the natural laws, or in my deductions from these premises. This, however, is precisely what the Author of the Warnings has not even attempted to do; he has preferred to be guided by the old solicitor's maxim: "When you have no case, abuse the plaintiff's attorney."

I do not propose to follow the Author of the Warnings in the personal tone that he has introduced into the discussion, except to say that the theory—if theory it be—that a falling barometer is apt to correspond with an increase in the percentage of firedamp in the air of collieries is certainly not my theory, and originated long before my time. As the Author of the Warnings implies that these views necessarily connect colliery explosions with a low barometer, it seems worth while repeating that this is not my opinion; all that I maintain is:—

(1) Barometric variations are only a contributory cause, and a relatively unimportant one, of colliery explosions.

(2) A falling barometer, or, to be more precise, a flattening downwards of the barometric gradient, is apt to be accompanied by an increase in the percentage of firedamp in the air of mines.

Thus W. Köhler has shown that a slow increase in the percentage of firedamp may be due to a steady high barometer, or even to a slow rise following upon a very rapid one, *i.e.* to a flattening of the barometric gradient.

The Author of the Warnings appears to attach much importance to the Seaham Colliery records. Seeing how fiercely he has accused everyone else of only using such facts as suit them, it might be expected that he, at any rate, would be above reproach in this respect; unfortunately, however, it would be difficult to find a worse offender than he is in the use he has made of these records. In the first place, he ought to have made it clear that these records do not show gas pressure in a

mine under normal conditions; they were taken in a sealed-off portion of Seaham Colliery after an explosion and an underground fire, and thus represent what took place under an entirely abnormal condition of the mine. Apart from this point, the Author of the Warnings contrives to give his reader the impression that Mr. Corbett's Seaham Colliery records entirely favour his own views, that high barometric pressure causes an increase in firedamp in mines; so far from this being the case, however, Mr. Corbett's own words (Trans. North Eng. Inst. Min. Eng., vol. xxxii., 1882–3, p. 310) are:—"It is well known that gas is frequently found in colliery workings before any fall of the barometer commences. . . . The barometer, so far as an indication showing that gas may be expected, cannot be said to be reliable." In the discussion of this paper, Mr. J. Daglish (*ibid.*, p. 311) said that he had made experiments at Hetton Colliery, and that "the results he arrived at were precisely such as were given by Mr. Corbett, namely, that there was no connection whatever between the variations of the barometer and the prevalence of gas in the galleries of the mine." The chief witness cited in his favour by the Author of the Warnings is thus seen to give evidence quite directly against him when he is quoted correctly. Further, if the Author of the Warnings attaches the importance that he appears to do to these records of pressure, why does he not quote the very well known and much more applicable experiments of Sir Lindsay Wood, who determined the pressure of firedamp in normal coal seams by boring holes into them and inserting pressure gauges? His general conclusions (Trans. North Eng. Inst. Min. Eng., vol. xxx., 1880–1, p. 224) are:—"There is no connection between the variations of the barometrical column and the temperature with the quantities of gas evolved"; only in one set of tests, namely, at Eppleton Colliery, was any connection traceable, and, respecting these, Sir Lindsay Wood (*ibid.*, p. 182) states:—"With the barometer steadily rising, the gas pressure (with one or two exceptions, when there was an increase) steadily decreased."

Personally, I attach relatively little importance to records of pressure alone, even to such careful ones as those of Sir Lindsay Wood, Nasse, Broockmann, &c.; in the absence of analyses, it is only a conjecture that the pressure was caused by firedamp, and in the case of Seaham Colliery it is quite likely that other gases were present in large quantity. I hold that there is only one correct method of attacking this question, as has already been pointed out by Oberbergrat G. Köhler, and that is by systematic chemical analyses of the return mine air combined with barometric observations, as has been done on several occasions on the Continent, *e.g.* by Hilt at the Gemeinschaft and Alt-Gourley pits at Aachen, and, above all, by W. Köhler at the Grand Duke Frederick pits at Karwin. All the observations corroborated each other, and agree with the summary of W. Köhler:—"The proportion of firedamp in the air of the mine decreases in general with rising atmospheric pressure, and increases with falling atmospheric pressure. The proportion of firedamp increases the more rapidly the more steeply the curve of atmospheric pressure descends, and decreases the faster the more steeply the curve of atmospheric pressure rises." Harzé in Belgium and Behrens in Westphalia have confirmed these conclusions in their elaborate works on the subject. All this is the result of accurately observed facts, into none of which "theory" enters. All workers and observers in this subject have come to one of two conclusions, either that barometric variations have no decisive influence on the evolution of gas, or else that a falling barometric gradient increases the outflow of gas. Not a single writer, so far as I know, shows that a rising barometer increases the evolution of firedamp. Whilst most English authorities hold the first view, the universally held opinion in Germany is summed up thus by the well-known Saxon authority, E. Treptow:—"Im besonderen ist es als erwiesen anzusehen, dass nach einem schnellen Fallen des Barometers stärkere Gasentwickelungen stattfinden. Es ist daher die fortlaufende Beobachtung der Barometerstände von grosser Wichtigkeit; tritt ein Barometersturz ein, so ist besondere Vorsicht geboten. Ein Barometerfall von 1 mm. in einer Stunde ist schon sehr bedeutend." (In particular, it may be looked upon as demonstrated that, after a rapid fall of the barometer, stronger evolutions of gas take place. The continual observation of the height of the barometer is therefore of great importance; if a drop of the barometer takes place, special caution must be observed. A fall of the barometer of 1 mm. per hour is already very serious.)

It is facts like the above-quoted analyses that alone can decide this question; it is quite useless to inquire whether the barometer was high or low at the time of any particular colliery explosion, because a serious colliery explosion can only be brought about by the fortuitous coincidence of a number of contributory conditions, only one of which (and in all probability a relatively unimportant one) can be ascribed to the state of the barometer. The Author of the Warnings implies that my views have been influenced by newspaper statements as to the height of the barometer at the time of the great Courrières disaster; but not only do I, as I have said, regard such evidence as useless, but, above all, I would not commit the crowning absurdity of quoting in a discussion on firedamp the Courrières explosion, which is perfectly well known to have been a coal-dust explosion in a non-fiery pit.

Perhaps the most interesting point in the letter of the Author of the Warnings is his explanation of the reason why high barometric pressure must increase the percentage of gas in a pit; he believes that the increased pressure of the air squeezes down the earth's crust, and squeezes the gas out of it. I presume that he wishes this explanation to be taken seriously; but surely he has overlooked the very obvious fact that any increase of pressure on the surface of the earth, tending to squeeze gas out, is counterbalanced by an exactly equal increase of pressure upon the face of the coal in the mine, tending to keep the gas in, and that no variation of atmospheric pressure can thus disturb the previously existing *régime*. Even if this were not so, and if the crust of the earth could respond to such pressures, they are too insignificant to have any practical effect. An enormous fluctuation of barometric pressure, such as a rise of 1 inch, would correspond to a pressure on the earth's crust of only 70 lb. per square foot, or a good deal less than that of an ordinary crowd of people standing on the ground; the very suggestion that such a trifling weight can have any effect through thousands, or even hundreds, of feet of strata is so absurd as to require no refutation, and least of all to the mining engineer who has had to timber underground workings, and who knows that the roof pressure in a mine must be gauged, not in pounds, but in tons on the square foot, and that 70 lb. more or less will make no practical difference whatever. That such a theory should be relied on in defence of the Colliery Warnings surely justifies their opposition by mining engineers, and forms an emphatic endorsement of the verdict of the last Royal Commission—which, by the way, was not composed of professors of mining or theorists—upon these Warnings as *misleading and serving no useful purpose.*

H. LOUIS.

The Afterglow of Electric Discharge in Nitrogen.

IN a paper published in the current number of the Physical Society's Proceedings, I showed that the yellow afterglow produced by the electric discharge in rarefied air is due to the oxidation of nitric oxide by ozone, both substances being formed in the discharge. In a second paper, in course of publication, it is shown that several other oxidisable gases or vapours inflame spontaneously when mixed with ozone at a low pressure, and burn with phosphorescent flames of low temperature.

An afterglow in nitrogen has been recorded by Mr. Perceval Lewis (*Phys. Zeit.*, v., p. 546, 1904) which is obtained only with condenser discharges. This glow is orange in colour, and possesses a visual spectrum of three bright bands in the green, yellow, and red regions, in contrast to the continuous spectrum of the glow which I have traced to nitric oxide and ozone.

I have recently experimented with Lewis's nitrogen glow, using the method, introduced by Dewar in 1888, of drawing a continuous current of the gas through the vacuum tube into another vessel on its way to the pump.